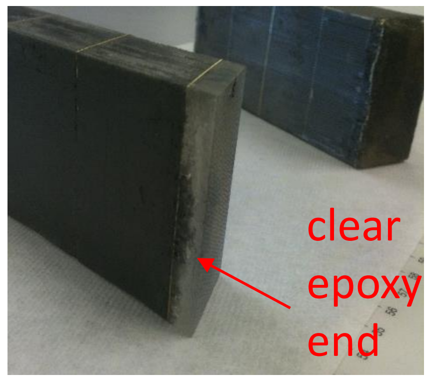
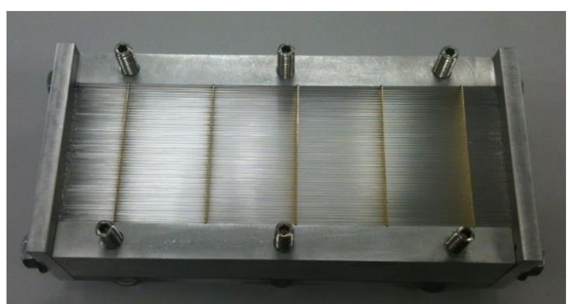
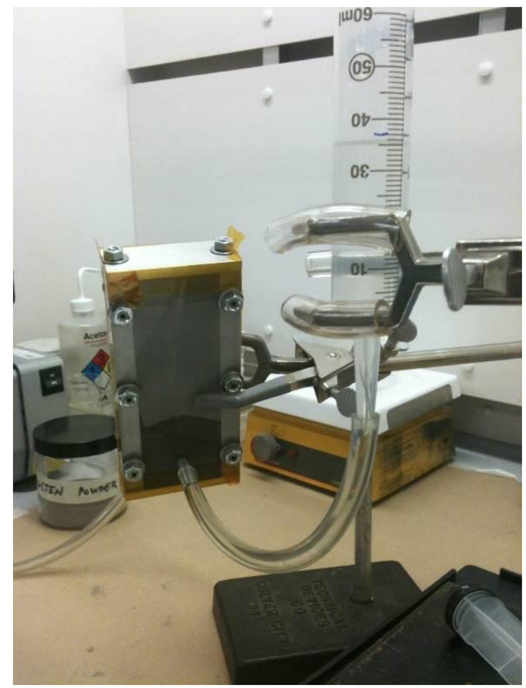
1D Projective Block production at BNL

- Developed mold and process based on UCLA SPACAL process by Oleg Tsai
- We produced 5 1D modules at BNL using this process







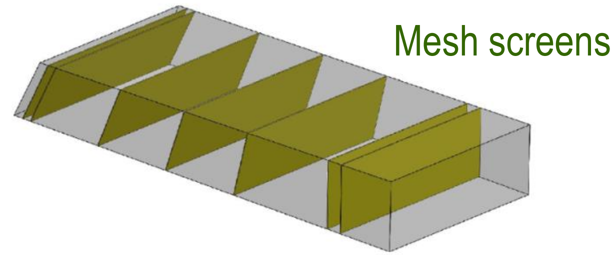
1D Projective blocks produced at THP

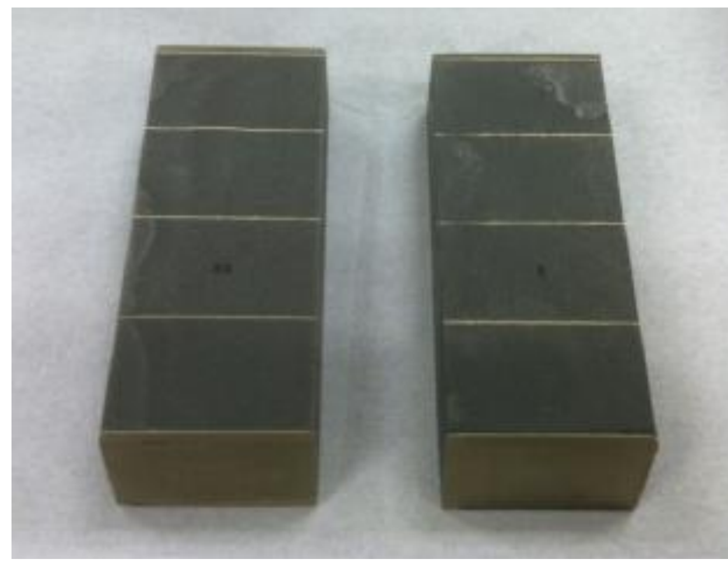
- Scale up block production processes to industrial scale

THP Tungsten HEAVY Powder, Inc.

Supplier of tungsten powder

1D Projective

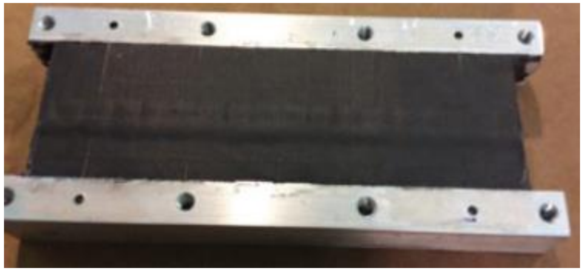




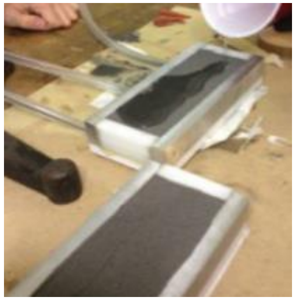
- 6 modules have been sent to BNL for Q/A measurements while they have been developing their production process
- They are continuing to improve the quality and uniformity of the modules
- Module densities ~ 9.65 g/cm^3

1D Projective Block production at UIUC

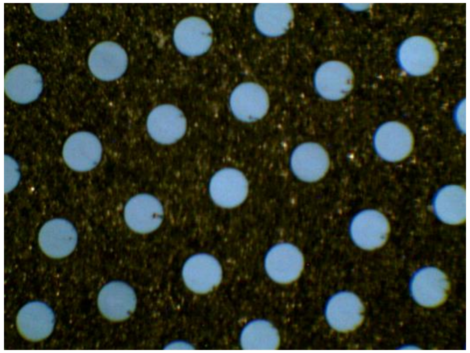
- Scale up block production processes to industrial scale
- Including end finishing to prepare readout surface – diamond cutting



8 modules have been produced (10/27/15) for the 1D projective prototype

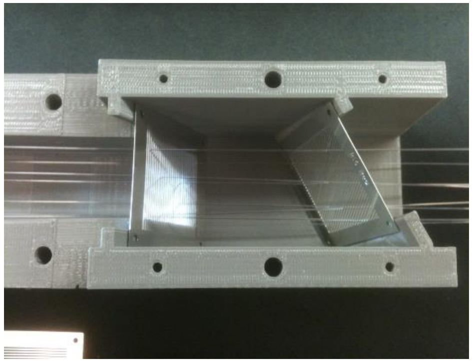


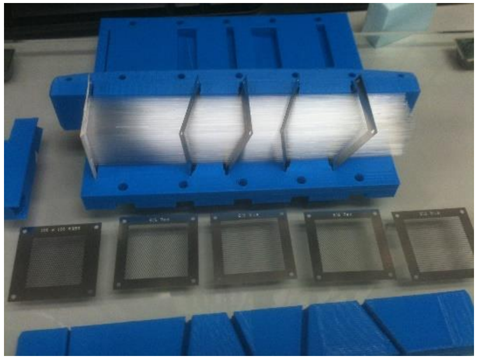
Fly cutting procedure produces high quality end finish that eliminates the need for clear epoxy ends, and doesn't require further polishing

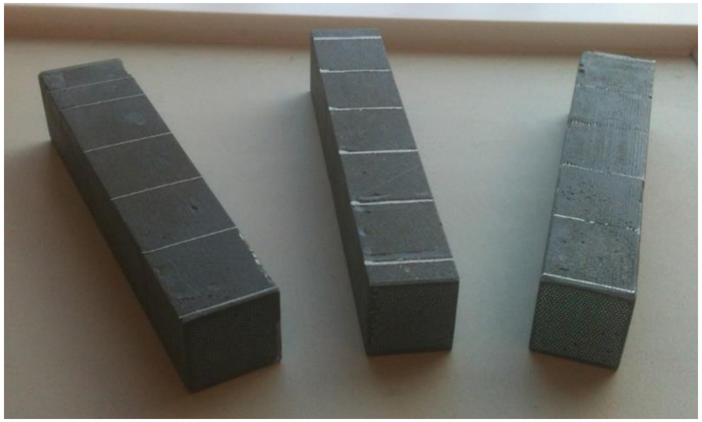


2D Projective Block production at BNL

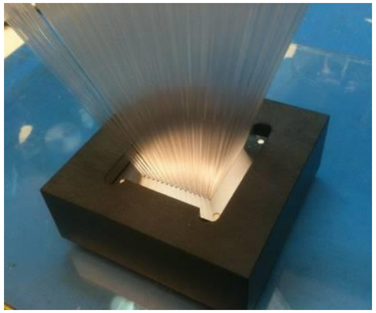
- Developed molds and processes for 2 techniques:
  - "tilted screen" uses a series of angled wire frames to taper the array of fibers inside the tower

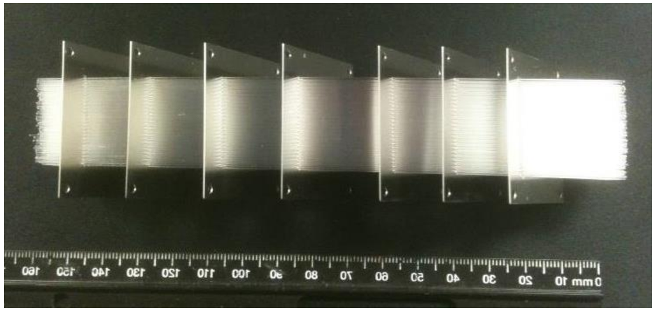


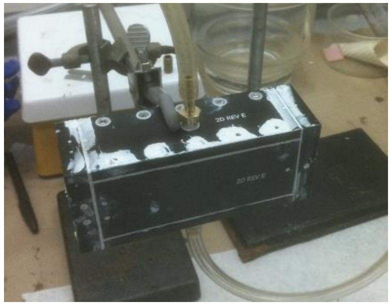




  - "tapered hole meshes" uses a series of meshes each with slightly different hole spacing to position the fibers
  - produced first 2D tapered SPACAL blocks at BNL

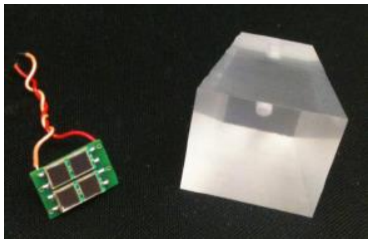


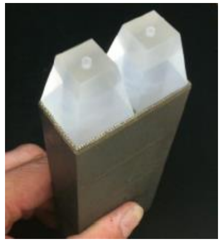


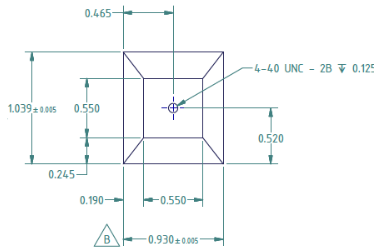


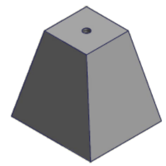
Light Guides

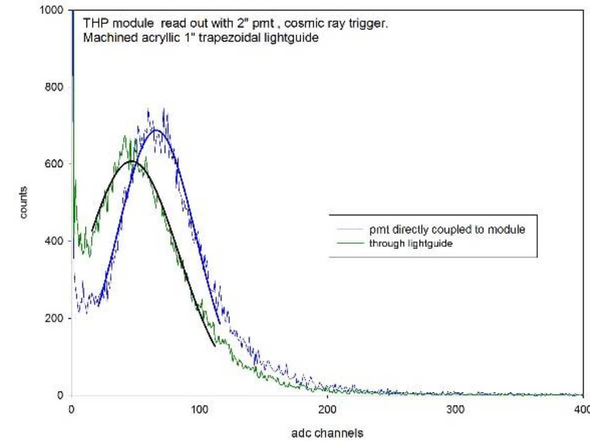
- Short light guide is used to collect light from tower (24 mm x 24 mm = 576 mm^2) onto 4 SiPMs (9mm^2 x 4 = 36mm^2 $\Rightarrow$ ~ 6%)
- Our first prototype will use an acrylic trapezoidal pyramid shape



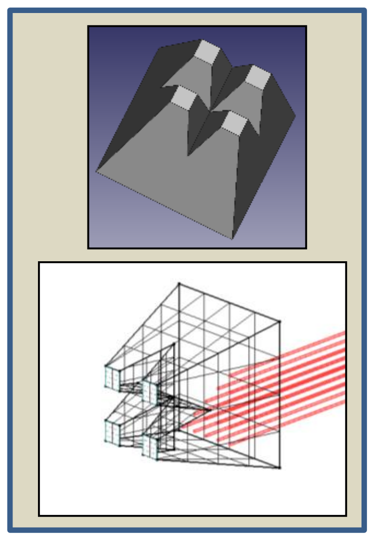


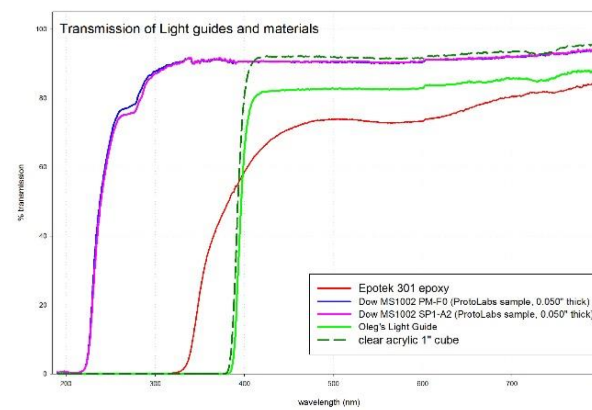






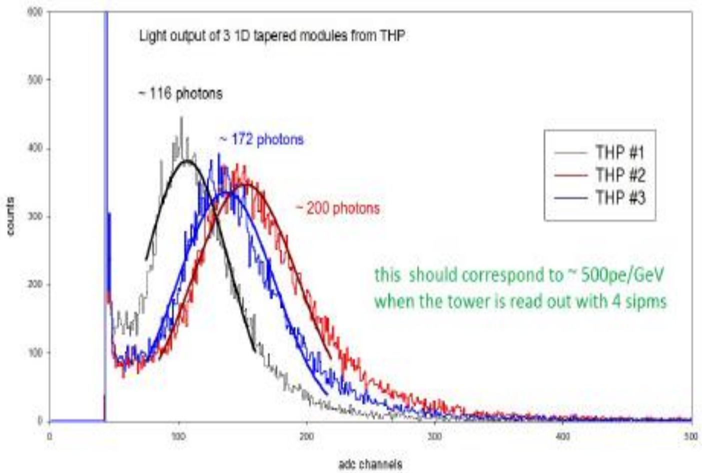
- Light collection efficiency ~ 70% for complete coverage of readout end (e.g., PMT)
- Efficiency with 4 SiPMs ~ 30%
- All light guides for first prototype have been fabricated
- We are continuing simulation work to improve the light guide design to increasing uniformity and efficiency



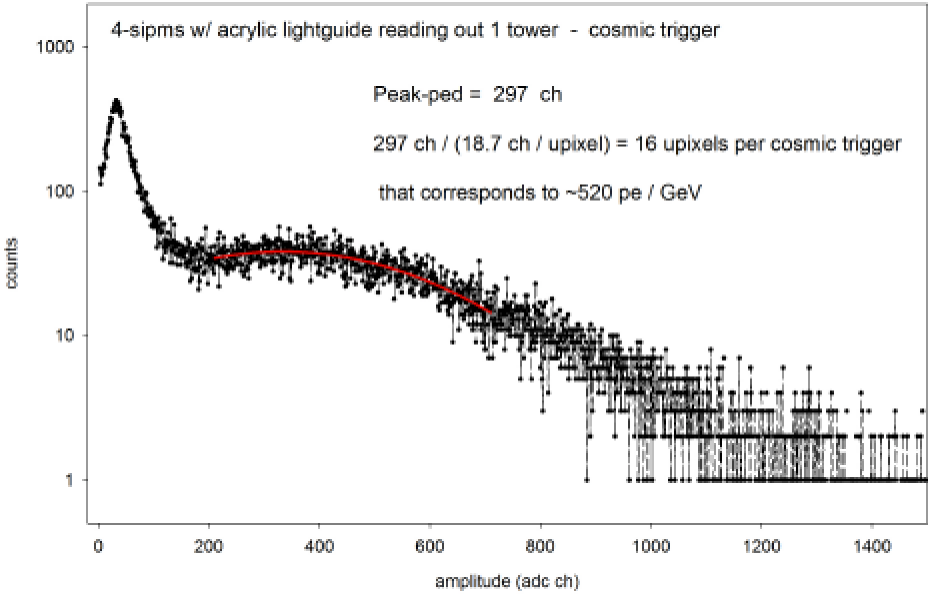


Tungsten/fiber/epoxy block Light Output

- Measured light output of THP blocks with PMT and with light guide + SiPMs with cosmic rays (traversing module transversley, E_{dep} ~ 30 MeV)



Light output measured with PMT with full coverage of module end



Light yield (p.e./MeV) measured with 4 SiPMs and light guide

Plans for Future Prototype Testing

Fermilab Test Beam

Central Rapidity Prototype (Spring 2016)

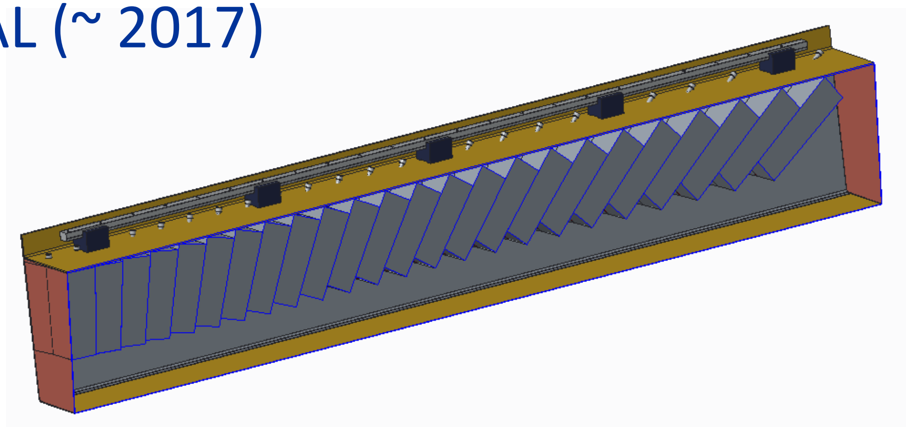
- 5x5 tower HCAL
- 8x8 tower EMCAL (1D projective)

Large Rapidity Prototype (Fall 2016)

- 5x5 tower HCAL
- 8x8 tower EMCAL (2D projective)

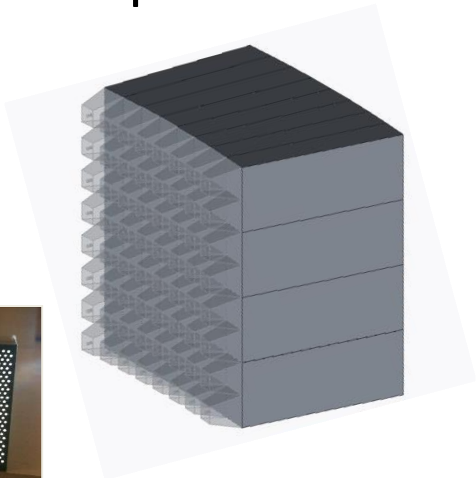
Pre-Production Prototype EMCAL (~ 2017)

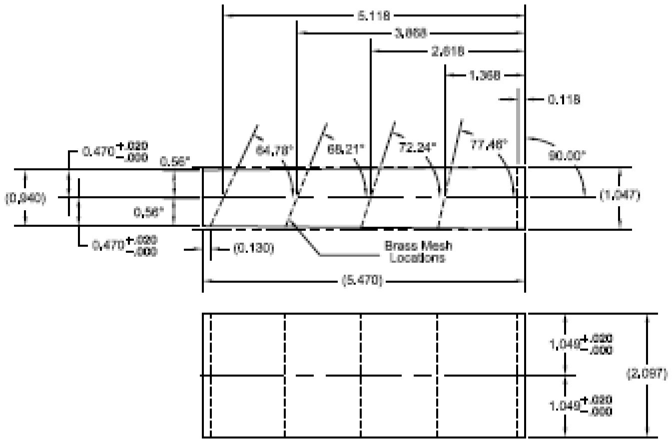
- 1 EMCAL Sector (384 towers)

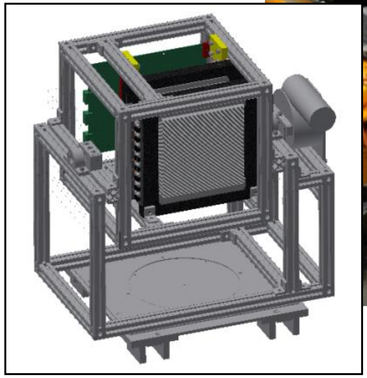


1D Projective Prototype

- To be tested with HCal prototype in FermiLab TBF in April 2016
- 32 1x2 blocks - 8x8 array of towers
- Re-purpose existing support stand
- Block are being produced by UIUC and THP
- SiPMs on hand
- Light guides have been produced







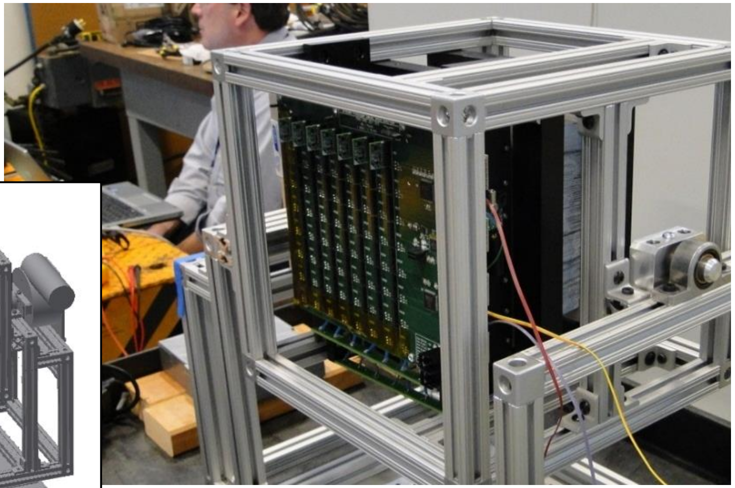
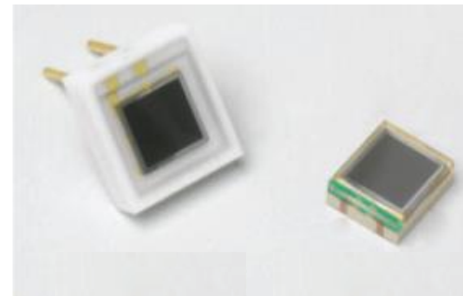


Photo Sensors

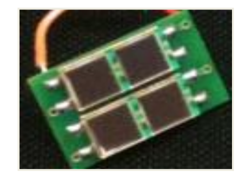
- Silicon Photomultipliers (SiPMs/MPPCs)
- Gain ~ 2×10^5, PDE = 25%
- Dynamic range > 10^4

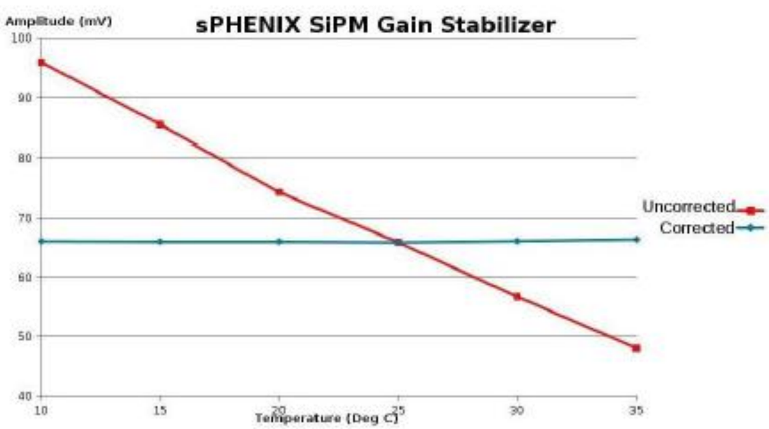
  15 μm pixel device $\rightarrow$ 40K pixels
- Work inside magnetic field
- Large gain dependence on temperature
- Large dark count rate (~ 1 Mcps)
- Susceptible to radiation damage from neutrons
- four 3mm x 3mm SiPMs passively summed for each tower

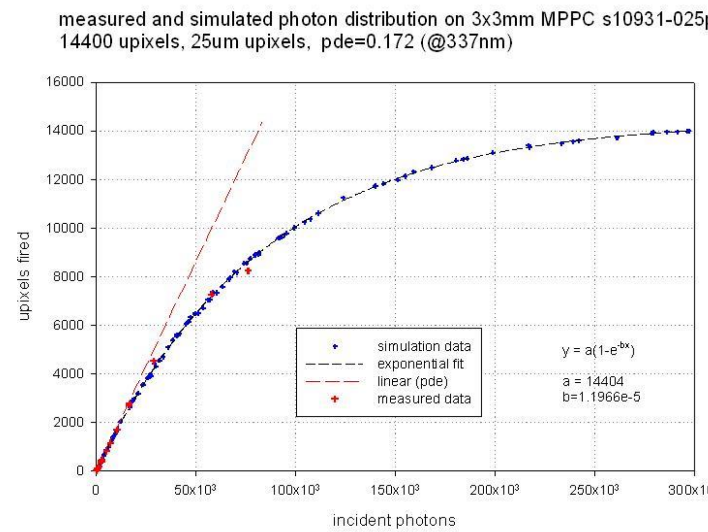
Current choice for baseline design



Hamamatsu S12572-015P
3x3 mm^3 MPPC

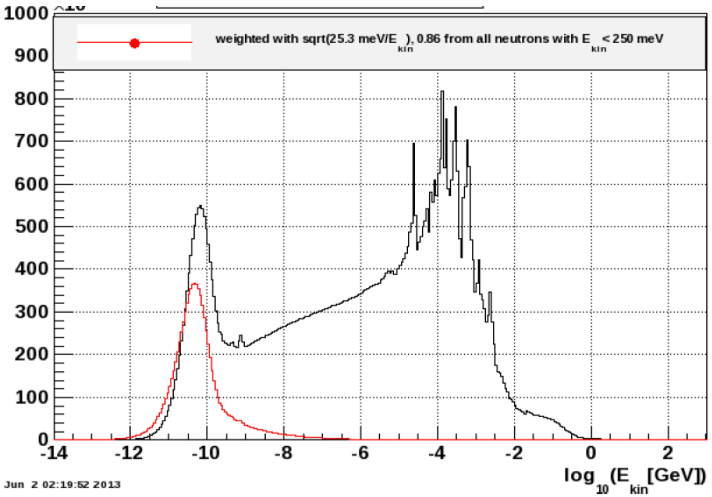




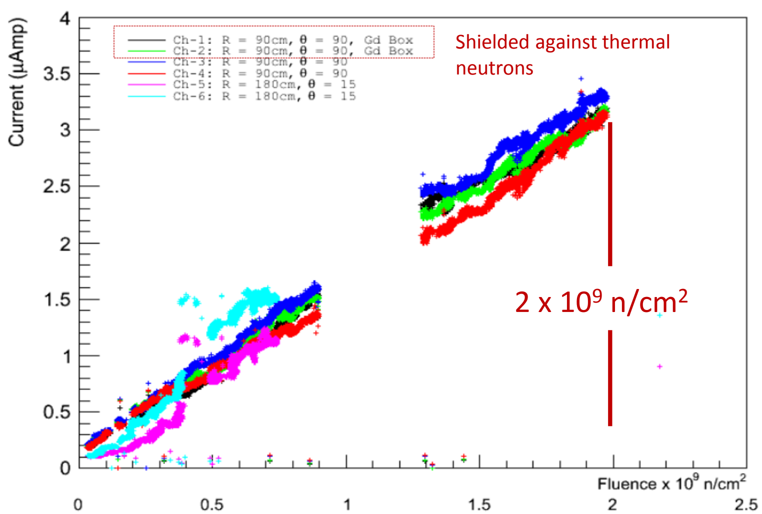


Radiation Damage in SiPMs

Estimated neutron flux in the STAR IR



Measured neutron flux in the PHENIX IR



Damage is caused mainly by neutrons (E ~ MeV)

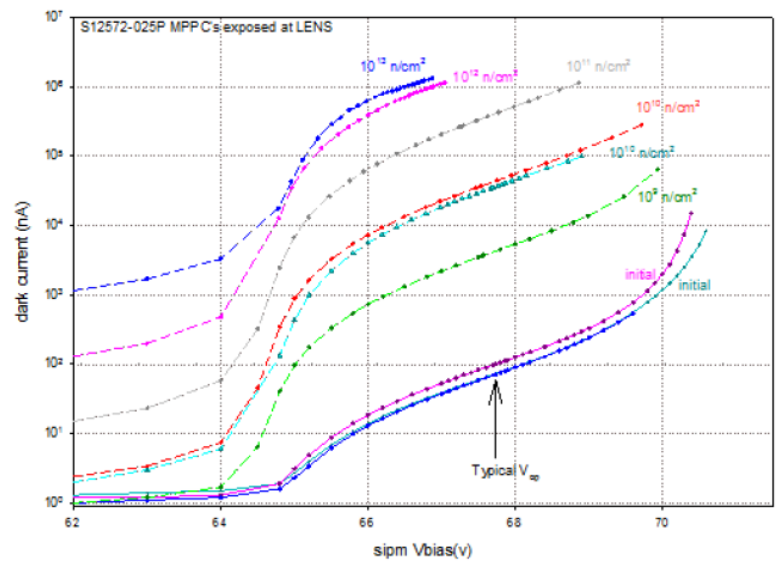
Measure thermal neutron flux in RHIC IR and estimate MeV equivalent neutrons using MC

Estimates in STAR for 2013 run (L=526 pb^{-1}):

R= 3-8 cm, |Z| < 10 cm : Φ_{eq} ~ 8x10^{10} n/cm^2

R= 100 cm, Z = 675 cm : Φ_{eq} ~ 2.2x10^{10} n/cm^2

Neutron measurements at the Indiana University LENS Facility

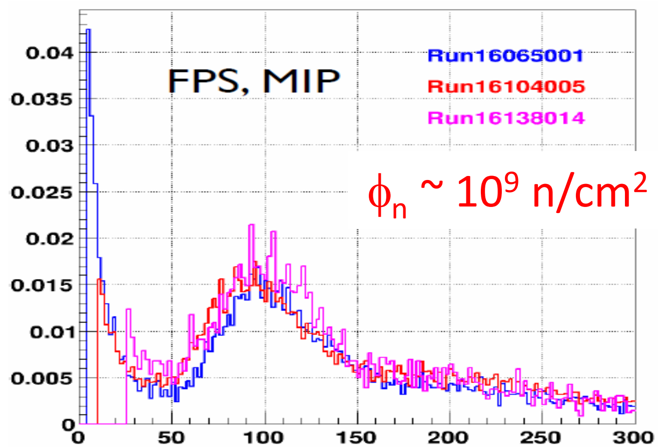


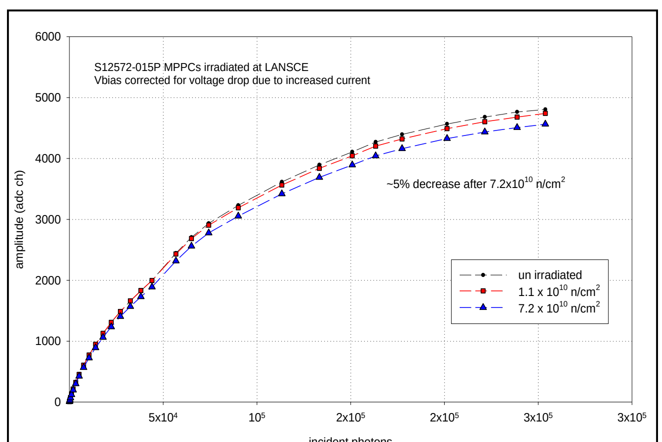
Radiation Damage in SiPMs

Primary effect seems to be increase in noise and not loss of PDE

Hamamatsu S12572-025P

MIP peak for STAR Forward Preshower detector during RHIC Run 15





- Operationally we plan to keep V_b constant for currents up to ~ 1 mA
- Will require cooling to maintain ~ 20° C
- Radiation damage studies suggest that we will have a decrease in signal amplitudes of a few % after about 4 years of running

Issues and Concerns

- Loading the fibers into the stacked screens is time consuming
- Consistently positioning the fibers in the blocks
  - fiber position is less constrained as distance from mesh increases
- Module density
  - target average module density is 10 g/cm^3
  - THP has shown that they can achieve this with centrifuging
  - BNL and UIUC modules have been ~ 9.7 g/cm^3
- Module end preparation to prepare readout surface
  - eliminating the clear epoxy region simplifies the production process by eliminating a gluing step, but it then requires finishing a tungsten powder/fiber surface.
- SiPM Radiation damage
  - increasing dark current is a concern
  - characterize SiPM damage at fluences of 10^{11} to 10^{13} n/cm^2 along with better estimates of neutron fluences in the sPHENIX IR.